UDC 629.783(045)

**Stojce Dimov Ilcev,** Prof.

# IMPLEMENTATION OF AERONAUTICAL LOCAL SATELLITE AUGMENTATION SYSTEM

Mangosuthu University of Technology, Durban, South Africa
E-mail: ilcev@mut.ac.za

**Abstract.** This paper introduces development and implementation of new Local Satellite Augmentation System as an integration component of the Regional Satellite Augmentation System (RSAS) employing current and new Satellite Communications, Navigation and Surveillance (CNS) for improvement of the Air Traffic Control (ATC) and Air Traffic Management (ATM) and for enhancement safety systems including transport security and control of flights in all stages, airport approaching, landing, departures and all movements over airport surface areas. The current first generation of the Global Navigation Satellite System GNSS-1 applications are represented by fundamental military solutions for Position, Velocity and Time of the satellite navigation and determination systems such as the US GPS and Russian GLONASS (Former-USSR) requirements, respectively. The establishment of Aeronautical CNS is also discussed as a part of Global Satellite Augmentation Systems of GPS and GLONASS systems integrated with existing and future RSAS and LSAS in airports areas. Specific influence and factors related to the Comparison of the Current and New Aeronautical CNS System including the Integration of RSAS and GNSS solutions are discussed and packet of facts is determined to maximize the new satellite Automatic Dependent Surveillance System (ADSS) and Special Effects of the RSAS Networks. The possible future integration of RSAS and GNSS and the common proposal of the satellite Surface Movement Guidance and Control are presented in the changeless ways as of importance for future enfacements of ATC and ATM for any hypothetical airport infrastructure.

**Keywords:** ADSS, ATC, ATM, CNS, GSAS, LRAS, RSAS, SMGC, Special Effects of RSAS.

## Introduction

The GPS and GLONASS are first generation of Global Navigation Satellite System (GNSS-1) infrastructures giving positions to about 30 m, using simple GPS/GLONASS receivers (Rx) onboard aircraft or ships, and they therefore suffer from certain weaknesses, which make them impossible to be used as the sole means of navigation for ships, particularly for land (road and rail) and aviation applications. In this sense, technically GPS or GLONASS systems used autonomously are incapable of meeting civil maritime, land and especially aeronautical mobile very high requirements for integrity, position availability and determination precision in particular for Traffic Control and Management (TCM) and are insufficient for certain very critical navigation and flight stages [1; 2].

The Communications, Navigation and Surveillance (CNS) improvements include new solutions for better management and operation of aircraft and they are needed more than ever before, because of world aircraft fleet expansion. Namely, the world's commercial airways fleet is expected to double in the next 20 years. This will result in crowded routes leading to fuel wastage and delays, which could cost millions of dollars annually. The potential benefits will assist ATC to cope with increased traffic as well as improving safety and security and reducing the infrastructures needed on the ground. The problem of hijacking can be solved similarly as a piracy, robbery and terrorist attacks on ships developed by International Maritime Organization (IMO). International Civil Aviation Organization (ICAO) will have a vital role in development International Aircraft and Airport Security (IAAS) system and design an Approaching and Airport Control System (AACS) by special code augmentation satellite CNS including tracking and monitoring of all aircraft and vehicles circulation in and out of the airport area. To enhance safety and security of intercontinental flying and control on the airport surface is necessary to abandon long term Future Air Navigation Systems (FANS) of ICAO and develop new Global Aeronautical Distress and Safety System (GADSS), which is shortly introduced in the book Global Mobile Satellite Communications (GMSC) written by author of this paper [3].

Because these two systems are developed to provide navigation particulars of position and speed in the airplane cockpits, only captains of the aircraft know very well their position and speed, but people in ATC cannot get in all circumstances their flight data without service of new CNS facilities. Besides of accuracy of GPS or GLONASS, without new CNS is not possible to provide full ATM in every critical or unusual situation. Also these two GNSS systems are initially developed for military utilization only, and now are also serving for all transport civilian applications worldwide, so many countries and international organizations would never be dependent on or even entrust people's safety to GNSS systems controlled by one or two countries. However, RSAS networks were recently developed to improve the mentioned deficiencies of current military systems and to meet the present transportation civilian requirements for high-operating Integrity, Continuity, Accuracy and Availability (ICAA). These new developed and operational CNS solutions are the US Wide Area Augmentation System (WAAS), the European Geostationary Navigation Overlay System (EGNOS) and Japanese MTSAT Satellite-based Augmentation System (MSAS), which are able to provide CNS via Geostationary Earth Orbit (GEO) satellite constellation [3; 4].

These three RSAS networks are integration segments of the GSAS and parts of the interoperable GNSS-1 architecture of GPS and GLONASS and new GNSS-2 of the European Galileo and Chinese Compass. This includes Inmarsat CNSO (Civil Navigation Satellite Overlay) and new projects of RSAS infrastructures, such as the Russian System of Differential Correction and Monitoring (SDCM), the Chinese Satellite Navigation Augmentation System (SNAS), Indian GPS/GLONASS and GEOS Augmented Navigation (GAGAN) and African Satellite Augmentation System (ASAS). Only remain something to be done in South America and Australia for establishment of the GSAS infrastructure globally, illustrated in fig. 1.

The RSAS solutions are based on the GNSS-1 signals for augmentation, which evolution is known as the GSAS network and which service provides an overlay function and supplementary services. The future ASAS Space Segment will be consisted by existing GEO birds, such as Inmarsat-4 and Artemis or it will implement own satellite constellation, to transmit overlay signals almost identical to those of GPS and GLONASS and provide CNS service. The South African firm IS Marine Radio, as inventor of the Project will have overall responsibility for the design and development of the ASAS network with all governments in the Region.

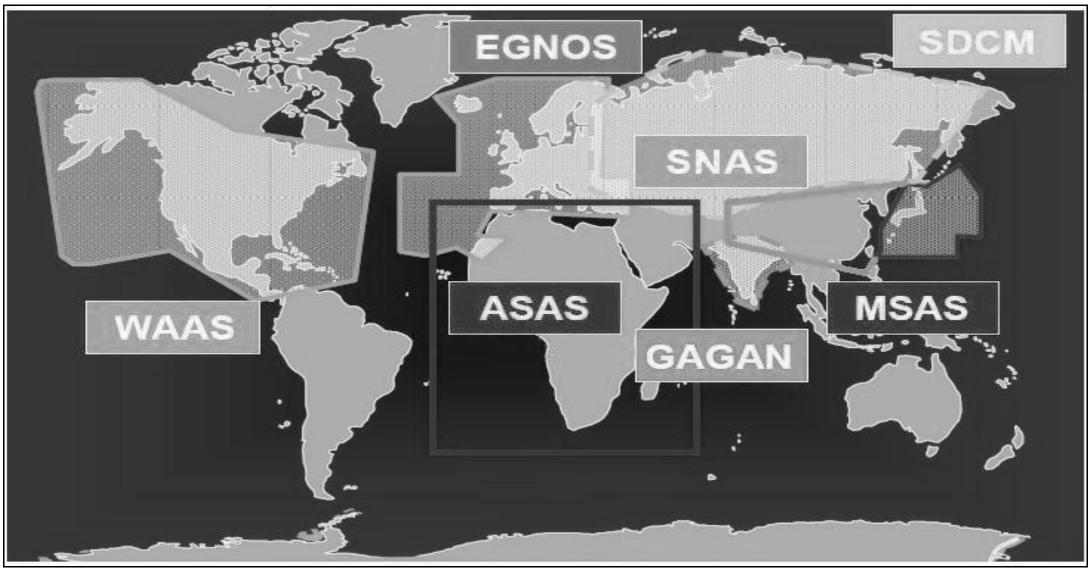


Fig. 1. GSAS Network Configuration

**GNSS Applications**

The RSAS infrastructures are available globally to enhance current standalone GPS and GLONASS system PVT performances for maritime, land (road and rail) and aeronautical transport applications. User devices can be configured to make integration of internal sensors for added robustness in the presence of jamming, or to aid in vehicle navigation when the satellite signals are blocked in the "urban canyons" of tall city buildings or mountainous environment and heavy clouds. In the similar sense, some special transport solutions, such as maritime and especially aeronautical, require far more CNS accuracy and reliability than it can be provided by current military GPS and GLONASS space infrastructures [1; 3].

Moreover, positioning accuracy can be improved by removing the correlated errors between two or more satellites GPS and/or GLONASS Rx terminals performing range measurements to the same satellites. This type of Rx is in fact Reference Receiver (RR) surveyed in, because its geographical location is precisely well known. However, one method of achieving common error removal is to take the difference between the RR terminals surveyed position and its electronically derived position at a discrete time point. These positions differences represent the error at the measurement time and are denoted as the differential correction, which information may be broadcast via GEO data link to the user receiving equipment, shown in fig. 2 [5].

In this case the user GPS, GLONASS or future Galileo and Compass augmented Rx can remove the error from its received data. Alternatively, in non-real-time technique GNSS solutions, the differential corrections can be stored along with the user's positional data and will be applied after the data collection period, which is typically used in surveying applications. If the RR or Ground Monitoring Station (GMS) of the mobile users, the mode is usually referred to as local area differential, similar to the US DGPS for Maritime applications. At this point, as the distance increases between the users and the GMS cites, some ranging errors become decorrelated. This problem can be overcome by installing a network consisting a number of GMS reference sites throughout a large geographic area, such as a region or continent and broadcasting the Differential Corrections (DC) via GEO satellites. At this point, the new projected ASAS network has to cover entire African Continent and the Middle East region enabling CNS solutions for ATC and ATM [3; 5].

Therefore, all GMS sites connected by Terrestrial Telecommunication Networks (TTN) or Digital Video Broadcasting-Return Channel via Satellite (DVB-RCS) are collecting data to one or more Ground Control Stations (GCS), where DC is performed and satellite signal integrity is checked. Then, the GCS sends the corrections and integrity data to a major Ground Earth Station (GES) for uplink to the GEO satellite.

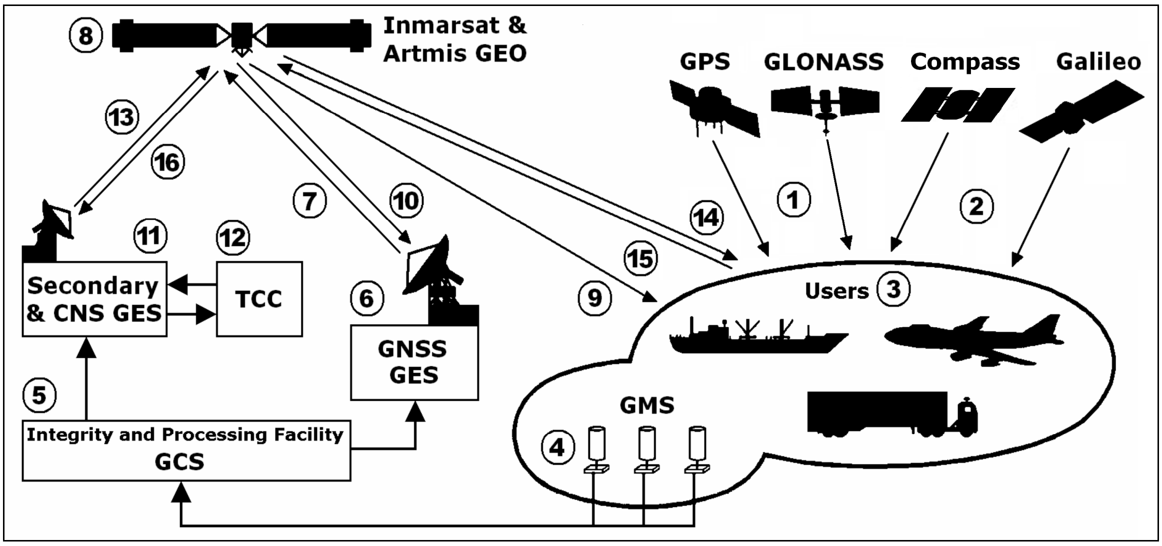


Fig. 2. RSAS Network Configuration

This differential technique is referred to as the wide area differential system, which is implemented by GNSS system known as a Wide Augmentation Area (WAA), while another system known as a Local Augmentation Area (LAA) is an implementation of a local area differential. The LAA solution is an implementation for airports and seaports including for approaching utilizations. The WAA is an implementation of a wide area differential system for wide area CNS maritime, land and aeronautical applications, such as Inmarsat CNSO and the newly developed Satellite Augmentation WAAS in USA, which includes the Canadian WAAS (CWAAS), the European EGNOS and Japanese MSAS, especially for ATC and ATM [4; 6].

These three operational systems are part of the worldwide GSAS network and integration segments of the future interoperable GNSS-1 infrastructure of GPS and GLONASS and GNSS-2 of Galileo and Compass, including CNSO as a part of GNSS offering this service via Inmarsat-3/4 and Artemis spacecraft. The author of this paper for the first time is using more adequate nomenclature GSAS than Satellite-based Augmentation System (SBAS) of ICAO, which has to be adopted as the more common designation in the field of CNS [3].

As discussed earlier, the current three RSAS networks in development phase are the Russian SDCM, Chinese SNAS and Indian GAGAN, while African Continent and Middle East have to start sometimes in 2011 with development ASAS project. In this sense, development of forthcoming RSAS projects in Australia and South America will complete Augmented CNS system worldwide, known as an GSAS Network [5].

Three operational RSAS together with Inmarsat CNSO are interoperable, compatible and each constituted of a network of GPS or GLONASS observation stations and own and/or leased GEO communication satellites. Namely, the Inmarsat CNSO system offers on leasing GNSS payload, while the European system EGNOS, which provides precision to within about 5 m is operational since 2009. In fact, it also constitutes the first steps towards forthcoming Galileo, the future European system for civilian global navigation by satellite. The EGNOS system uses leased Inmarsat AOR-E and IOR satellites and ESA ARTEMIS satellite. Thus, the US-based WAAS is using Inmarsat and own satellites and Japanese MSAS is using its own multipurpose MTSAT spacecraft, both are operational from 2007 and 2008, respectively. Although the global positioning accuracy system associated with the overlay is a function of numerous technical factors, including the ground network architecture, the expected accuracy for the US Federal Aviation Administration (FAA) WAAS will be in the order of 7,6 m (2 drms, 95%) in the horizontal plane and 7,6 m (95%) in the vertical plane [5; 7].

**RSAS System Configuration**

The RSAS networks are designed and implemented as the primary means of satellite CNS for aeronautical routes in corridors over continents and oceans, control of airports approachings and managing all aircraft and vehicles movements on airports surface. In this sense, it will also serve for maritime course operations such as ocean crossings, navigation at open and close seas, coastal navigation, channels and passages, approachings to anchorages and ports, and inside of ports, and for land (road and railways) solutions [1; 8]:

It was intended to provide the following services:

1. The transmission of integrity and health information on each GPS or GLONASS satellite in real time to ensure all users do not use faulty satellites for navigation, known as the GNSS Integrity Channel (GIC).

2. The continuous transmission of ranging signals in addition to the GIC service, to supplement GPS, thereby increasing GPS/GLONASS signal availability. Increased signal availability also translates into an increase in Receiver Autonomous Integrity Monitoring (RAIM) availability, which is known as Ranging GIC (RGIC).

3. The transmission of GPS or GLONASS wide area differential corrections has, in addition to the GIC and RGIC services, to increase the accuracy of civil GPS and GLONASS signals. Namely, this feature has been called the Wide Area Differential GNSS (WADGNSS).

The combination of the Inmarsat overlay services and Artemis spacecraft will be referred to as the RSAS network illustrated in fig. 2. As observed previous figure, all mobile users (3) receive navigation signals (1) from GNSS-1 of GPS or GLONASS satellites. In the near future can be used GNSS-2 signals of Galileo and Compass satellites (2). These signals are also received by all reference GMS terminals of integrity monitoring networks (4) operated by governmental agencies in many countries within Africa and Middle East.

The monitored data are sent to a regional Integrity and Processing Facility of GCS (5), where the data is processed to form the integrity and WADGNSS correction messages, which are then forwarded to the Primary GNSS GES (6). At the GES, the navigation signals are precisely synchronized to a reference time and modulated with the GIC message data and WADGNSS corrections. The signals are sent to a satellite on the C-band uplink (7) via GNSS payload located in GEO Inmarsat and Artemis spacecraft (8), the augmented signals are frequency-translated to the mobile user on L1 and new L5-band (9) and to the C-band (10) used for maintaining the navigation signal timing loop. The timing of the signal is done in a very precise manner in order that the signal will appear as though it was generated on board the satellite as a GPS ranging signal. The Secondary GNSS GES can be installed in Communication CNS GES (11), as a hot standby in the event of failure at the Primary GNSS GES. The Traffic Control Centre (TCC) ground terminals (12) could send request to all particular mobiles for providing CNS information by Voice or Data, including new Voice, Data and Video over IP (VDVoIP) on C-band uplink (13) via Communication payload located in Inmarsat or Artemis spacecraft and on C-band downlink (14) to mobile users (3). The mobile users are able to send augmented CNS data on L-band uplink (15) via the same spacecraft and L-band downlink (16). The TCC sites are processing CNS data received from mobile users by Host and displaying on the surveillance screen their current positions very accurate and in the real time [13]. Therefore, the ASAS will be used as a primary means of navigation during all phases of traveling for all mobile applications [1; 3].

The RSAS space constellation could be formally consisted in the 24 operational GPS and 24 GLONASS satellites and minimum 3 GEO satellites. The GEO satellites downlink the data to the users on the GPS L1 RF with a modulation similar to that used by GPS. Information in the navigational message, when processed by an RSAS Rx, allows the GEO satellites to be used as additional GPS-like satellites, thus increasing the availability of the satellite constellation. In such a mode, the RSAS signal resembles a GPS signal origination from the Gold Code family of 1023 possible codes (19 signals from PRN 120-138).

## Comparison of the Current and New Aeronautical CNS System

Business or corporate airways and shipping companies have used for several decades HF communication for long-range voice and telex communications during intercontinental flights and sailing. Meanwhile, for short distances mobiles have used the well-known VHF/UHF radio on board aircraft. In the similar way, data communications are recently also in use, primarily for flight plan and worldwide weather and navigation warning reporting. Apart from data service for cabin crew, cabin voice solutions and passenger telephony have also been developed. Thus, all mobiles today are using traditional electronic and instrument navigations systems and for surveillance facilities they are employing radars.

The current communication facilities between aircraft and ATC are executed by Radio HF voice and telex and by VHF voice system; see Previous Communication Subsystem in fig. 3 [6]. The VHF link between aircraft on one the hand and Ground Radio Station (GRS) and TCC on the other, may have the possibility to be interfered with high mountainous terrain and to provide problems for ATC and ATM. However, the HF link may not be established due to lack of available frequencies, high frequency jamming, bad propagation, increased intermediation, unstable wave conditions and to very bad weather situation, heavy rain, deep clouds and extreme thunderstorms. The author of this paper has seagoing experience in traditional communications and navigation, so without new CNS in very bad weather will be not possible to navigate safely.

The current navigation possibilities for recording and processing Radio Direction Information (RDI) and Radio Direction Distance Information (RDDI) between aircraft and ATC are performed by ground landing navigation equipment, such as the Instrument Landing System (ILS), VHF Omnidirectional Ranging (VOR) and Distance Measuring Equipment (DME), illustrated by the Present Navigation Subsystem in fig. 4 [3].

This subsystem needs more time for ranging and secure aircraft landing, using an indirect way of flying in a semicircle, few onboard type of radars and other visual and electronic navigation aids.

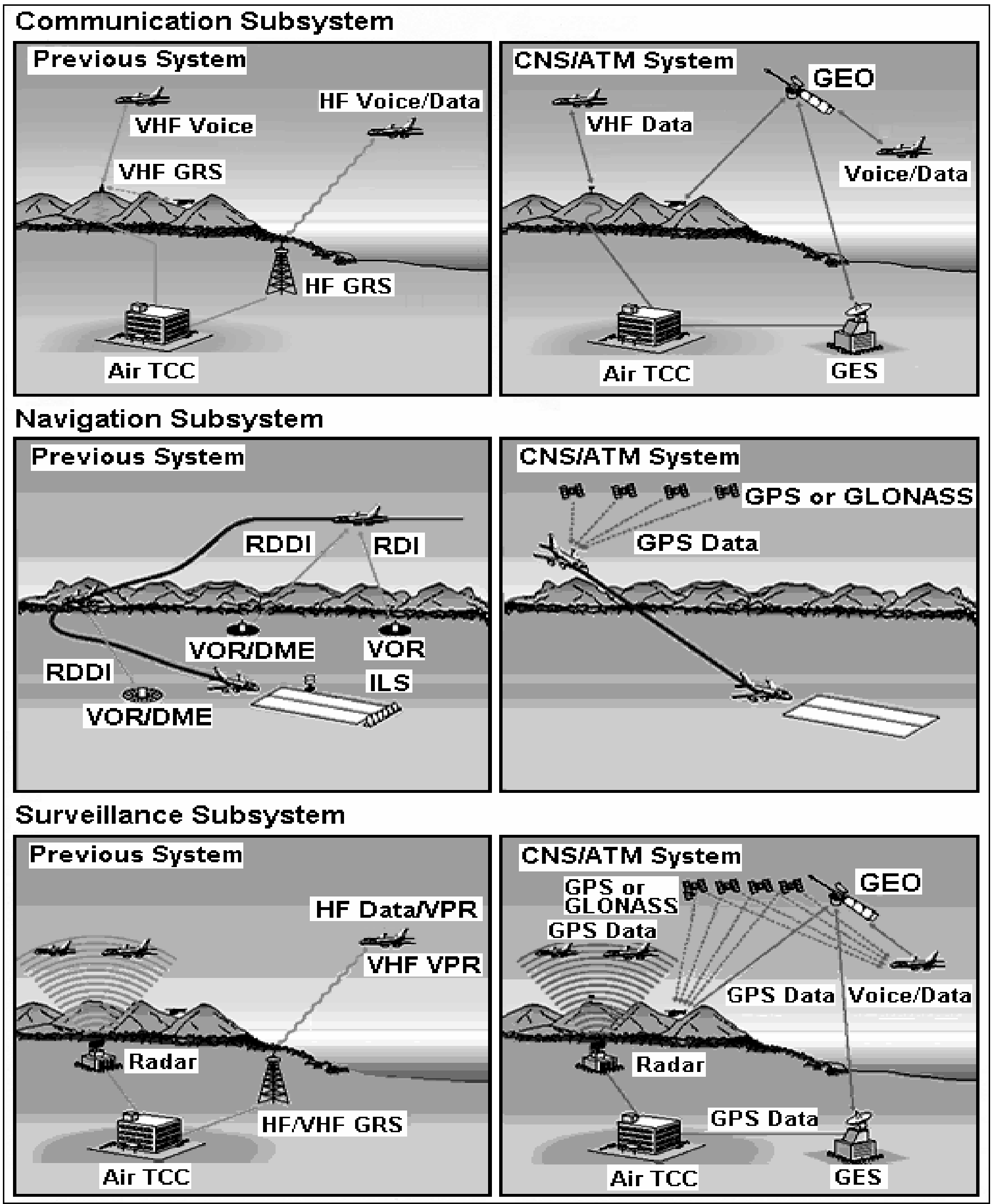


Fig. 3. Current and New CNS/ATM System

The current surveillance utilities for receiving Radar and HF Voice signals between aircraft and TCC are detected by Surveillance Radar and HF GRS terminals, respectively. This subsystem may have similar HF voice communications problems or when airplanes are flying behind high mountains they cannot be detected by Radar, see the Present Surveillance Subsystem in fig. 4. The very bad weather conditions, deep clouds and heavy rain could block radar signals totally and on the screen will be blanc picture without any reflected signals, so in this case cannot be visible surrounded obstacles or traffic of aircraft in the vicinity, and the navigation situation is becoming very critical and dangerous causing disasters [3; 8; 9].

On the contrary, the new CNS/ATM System utilizes the communications satellite and it will eliminate the possibility of interference by high mountains, see all three CNS Subsystems in fig. 4. At this point, new satellite communications, including a data link, improves both the quality and capacity of communications. The weather data, NOTAM and flight planning data and other aeronautical information may also be directly input to the Flight Management System (FMS). The GPS or GLONASS Navigation Subsystem Data provide almost a direct landing line, so surveillance information cannot be interfered with by mountainous terrain. The display on the screen will eliminate misunderstandings between controllers and aircraft pilots [1; 3; 6].

**Integration of RSAS and GNSS**

The GNSS system can be used worldwide to control the positions of aircraft and to manage air traffic. It supports aircraft flights well in all phases, including take-off and landing utilities. In fact, GNSS has some performance limitations and it cannot consistently provide the highly precise and safe information in the stable manner required for wide-area navigation services without implementation of RSAS.

To assure safe and efficient air traffic navigation of civil aircraft, GPS or GLONASS performance needs to be augmented with another system that provides the four ICAA essential elements of air navigation. As discussed, the current and new coming RSAS networks will be the regional interoperable WAA for GPS or GLONASS as integration segments of GSAS. The L1/L2RF band is nominated for the transmission of signals from GPS or GLONASS spacecraft in ground and air directions. These signals can be detected by the GMS and GNSS receivers of flying aircraft.

Moreover, the GEO GNSS satellite transponder uses the L1 frequency band to broadcast GPS or GLONASS augmentation signals in the direction of GES and aircraft [3; 7].

In particular, the Ku-band is used for unlinking GNSS augmentation signals to the ATAS GEO bird of RSAS network. The whole ground infrastructure and Network Communication System is controlled by GCS.

The components of the common RSAS Navigation System are illustrated in fig. 4.

To provide GPS or GLONASS augmentation information, all ground stations, which always monitor GNSS signals, are necessary in addition to GEO satellites. This special navigation infrastructure, which is composed of GEO satellite, GNSS wide-area augmentation system and these ground stations is RSAS or ATAS network.

The EGNOS system for instance, will implement number of Geostationary Ranging Stations (GRS)* for GEO ranging function, shown in fig. 4. These stations are different than GRS for communications, which uses a RF signals similar to GPS as a part of the Euridis ranging system and they can also serve ASAS such as: one in Toulouse, France, one in Kourou, French Guiana and one in Hartebeeshoek, South Africa [3; 9].

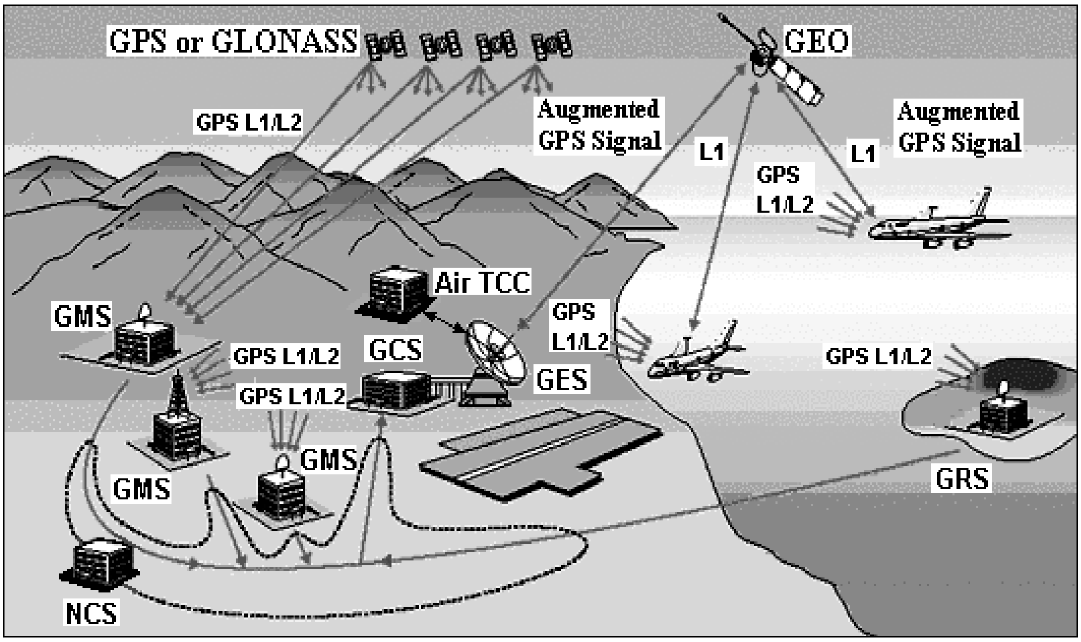


Fig. 4. Future ATAS Navigation System

**Automatic Dependent Surveillance System**

The current surveillance system is mainly supported by traditional VHF/UHF radio communications. This system enables display of real-time positions of the nearby approaching aircraft using radar and VHF/UHF voice radio equipment. Due to its limitations, the VHF/UHF service being used for domestic airspace cannot be provided over the ocean. Meanwhile, out of radar and VHF/UHF coverage and range on the oceanic routes, at present the aircraft position is regularly reported by HF radio voice and data terminals.

Consequently, the advanced CNS/ATM of the current and future RSAS utilizes the ADSS data function, which automatically reports all current aircraft positions measured by GPS to ATC, as illustrated in fig. 5 [3]. In such a manner, the approaching aircraft receives positioning data from GPS spacecraft and then sends its current position for recording and processing to the ATC Centre via GEO and adequate GES.

The display looks just like a pseudo-radar coverage picture screen. The coming ADSS system will increase air safety, reduce aircraft separation and improve functions and selection of the optimum route with more economical altitudes. In addition, the system will also increase the accuracy of each aircraft position and reduce the workload of both controller and pilot, which will improve safety and security. In this sense, aircraft can be operated in a more efficient manner and furthermore, since the areas where VHF/UHF radio does not reach due to mountainous terrain will disappear, small aircraft, including helicopters, will be able to obtain meteorological data on a regular basis.

These functions are mandatory to expand the traffic capacity of the entire air region and for the optimum air route selection under limited space and time restraints [3; 5].

**LSAS System Configuration**

The LSAS infrastructure is intended to complement the RSAS CNS service using a single differential correction that accounts for all expected common errors between a local reference and mobile users. The LSAS will broadcast navigation information in a localized volume area of airport or seaport using satellite service of any mentioned RSAS networks developed in Northern Hemisphere and future ASAS network.

In a more general sense, all above fixed or mobile applications will be able to assess CNS service inside of RSAS coverage directly by installing new equipment known as augmented GPS or GLONASS Rx terminals, and so to use more accurate positioning and determination data. In fig. 2 is illustrated scenario that all mobiles and GMS terminals directly are using not augmented signals of GPS or GLONASS satellites. To provide augmentation will be necessary to process not augmented signals in GCS, to eliminate all errors and produce augmented signals. However, in this stage any RSAS network standalone will be not able to produce augmented service for airports, seaports or any ground infrastructures. At this point, it will be necessary to be established some new infrastructure known as an LSAS, which can provide service for collecting augmented data from ships, land vehicles, airplanes or any ground user.

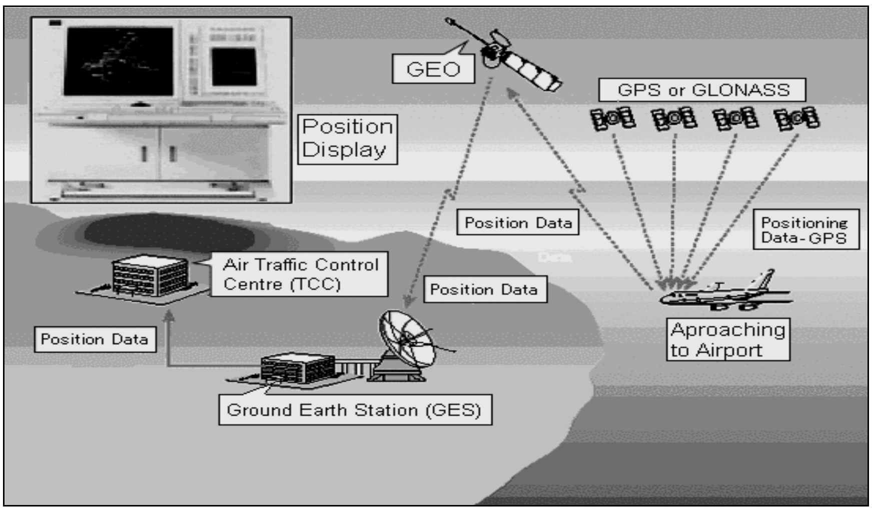


Fig. 5. Future ATAS Surveillance System

The navigation data of mobiles can be processed in the TCC cites and shown on the surveillance screen similar to the radar display and can be used for traffic control system at the see, on the ground and in the air. This scenario will be more important for establishment ATC or Maritime Traffic Control (MTC) service using augmented GNSS-1 signals from the aircraft or ships, respectively. In this sense, the LSAS network can be utilized for airports known as Surface Movement Guidance and Control (SMGC) and seaports as Coastal Movement Guidance and Control (CMGC) [1; 3].

In addition, using LSAS network and same RFID technologies can be developed an International Aircraft and Airport Security (IAAS) and an Approaching and Airport Control System (AACS) by special code, which will improve tracking and monitoring of all aircraft and vehicles circulation in and out of the airport area [3].

**Surface Movement Guidance and Control**

The new LSAS network can be also implemented as a Surface Movement Guidance and Control (SMGC) system integrated in any RSAS infrastructure. It is a special aeronautical security and control system that enables an airport's controller from Control Tower on the ground to collect all navigation and determination data from all aircraft, to process these signals and display on the surveillance screens. On the surveillance display can be visible positions and courses of all aircraft in vicinity flight areas, so they can be controlled, informed and managed by traffic controllers in any real time and space. In such a way, the LSAS traffic controller provides essential control, traffic management, guide and monitor all aircraft movements in the vicinity of the aircraft, approaching areas to the airport, aircraft movement in airport, including land vehicles in and around the airport, even in very poor visibility conditions at an approaching to the airport, what happened earlier with dust coming from eruption of volcano. Thus, the radar surveillance can be back up, while the LSAS controller issues CNS instructions to the aircraft's Pilots with the reference to a command surveillance display in a Control Tower that gives all aircraft position information in the vicinity detected via satellites and by sensors on the ground, shown in fig. 6.

The command monitor also displays reported position information of landing or departing aircraft and all auxiliary vehicles moving onto the airport's surface. This position is measured by GNSS, using data from GPS and GEO RSAS satellites. An airport controller is able to show the correct taxiway to pilots under poor visibility, by switching the taxiway centreline light and the stop bar light on or off. Otherwise, the development of head-down display and head-up display in the cockpit that gives information on routes and separation to other aircraft is in progress.

The following segments of SMGC are shown in fig. 6 [3]:

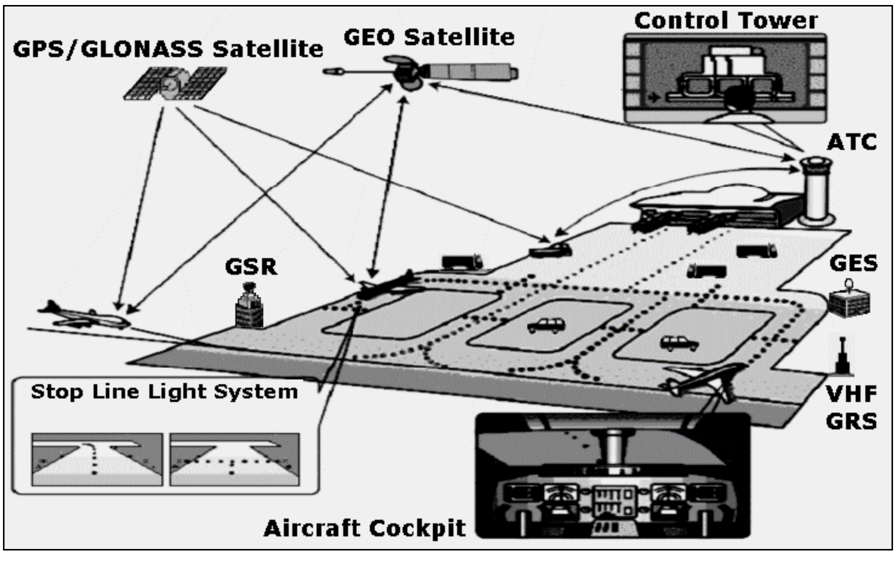


Fig. 6. SMGC Subsystem

1. GPS or GLONASS Satellite measures the aircraft or airport vehicles exact position.

2. RSAS is integrated with the GPS satellite positioning data network. In addition to complementing the GPS satellite, it also has the feature of communicating data between the aircraft and the ground facilities, pinpointing the aircraft's exact position.

3. Control Tower is the centre for monitoring the traffic situation on the landing strip around the airport's environment. The location of aircraft and vehicles is displayed on the command monitor of the control tower. The controller performs ground-controlled distance guidance for the aircraft and vehicles based on this data.

4. Stop Line Light System is managed by the controller, who gives guidance on whether the aircraft should proceed to the runway by turning on and off the central guidance line lights and stop line lights as a signal, indicating whether the aircraft should proceed or not.

5. Ground Surveillance Radar (GSR) is a part of previous system for ATC of aircraft approaching areas, in airport and around the airport air environment.

6. Very High Frequency (VHF) is Ground Radio Station (GRS) is a part of ARC via VHF or UHF Radio communications system.

7. Ground Earth Station (GES) is a main part of satellite communications system between GES terminals and ground telecommunication facilities via GEO satellite constellation.

8. Aircraft Cockpit displays the aircraft position and routes on the headwind protective glass (head-up displays) and instrument panel display (head-down display) [1; 3; 7].

## Conclusions

The CNS has been set up to identify the possible applications for global radio and satellite CNS, safety and security and control of aircraft, freight and passengers Search and Rescue (SAR) service in accordance with IMO and ICAO regulations and recommendations.

The new aeronautical satellite CNS using GEO satellites with Communication and GNSS payloads for ATC/ATM is designed to assist navigation both en-route PA and NPA as well as during landing and in airports. The potential benefits will assist ATC to cope with increased air traffic and to improve safety and reducing the infrastructure needed on the ground. The Communication GEO payloads usually at present employ transponders working on L/C, Ku and recently on Ka-bands for DVB-RCS scenario, which can be used for LSAS and to connect all airports in the region. Because that Ku-band is experiencing some transmission problems and is not so cost effective, there is proposal that Ka-band will substitute Ku-band even in mobile applications including aviation and maritime.

## References

1. *Ilcev, D. S.* Global Aeronautical Communications. Navigation and Surveillance (CNS). John Wiley, Chichester, 2010.

2. *Group* of Authors, Website of EGNOS (www.esa.int) & WAAS (www.gps.faa.gov), 2000-2010.

3. *Ilcev, D. S.* Global Mobile Satellite Communications for Maritime, Land and Aeronautical Applications. Springer, Boston, 2005.

4. *Kaplan, E.D.* Understanding GPS Principles and Applications, Artech House, Boston, 1996.

5. *Group* of Authors, MTSAT Update. NextSAT/10 CG. Japan Civil Aviation Bureau, MSAS, Tokyo, 2009.

6. *El-Rabbany*, A. Introduction to GPS. Artech House, Boston, 2002.

7. *Grewal, M.S.* and others, Global Positioning Systems, Inertial Navigation, and Integration. Wiley, London, 2008.

8. *Prasad, R. & Ruggieri, M.* Applied Satellite Navigation Using GPS, GALILEO, and Augmentation Systems. Artech House, Boston, 2005.

9. *Walker, J.* Advances in Mobile Information Systems. Artech House, Boston, 1999.

Received 30 March 2011.